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TABLE OF CONTENTS

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GENETIC ANALYSIS OF WEIGHT OF DOE RABBITS DURING GESTATION AND ITS PHENOTYPIC RELATIONSHIP WITH REPRODUCTIVE EFFICIENCY AT KINDLING

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Abstract

Data on 218 litters of Bauscat (BB) and Giza White (GG) rabbits were analyzed to study the effects of some non-genetic factors, and the genetic factors of sire of doe and doe within sire. Traits considered in the analysis were: doe's weight at conception (BWC) and at 1st (BW1), 2nd (BW2), 3rd (BW3) and 4th (BW4) weeks of gestation and litter size (LSB) and weight (LWB) at birth. Heritability, repeatability and phenotypic correlation parameters for these traits were estimated by mixed model analysis.

Weight of BB does exceeded that of GG does at conception and during gestation. LSB and LWB of GG were higher than those of BB. Birth year of sire and year of production effects on doe weight, LSB and LWB were not significant for BB and GG rabbits. Month-of-conception and parity effects on LSB and LWB were not significant for BB and GG rabbits, while they were significant sources of variation in most weights of BB and GG does during gestation. BB does conceived during September and October had the heaviest weights. The smallest size and lightest weight of litters were recorded for those BB does conceived during December while the largest and heaviest litters were recorded during January. No consistent patterns for parity and month-of-conception effects on doe weight and litter traits of GG rabbits were observed. Effects of sire of doe within year were significant ($P < 0.05$) for BWC of BB rabbits, all weights of GG and litter traits of BB but not significant for BB doe weight during gestation and litter traits of GG. Differences in doe weight due to doe effects were significant ($P < 0.001$), while they were not significant for litter traits in BB and GG rabbits. The percentages of variation due to sire effects were larger for GG than for BB doe weights, while a reverse trend for litter traits was observed. Estimates of heritability for BWC, BW1, and BW2 of BB ranged between 0.06 to 0.34, while no estimates were obtained for BW3 and BW4. Heritability estimates for GG doe weight ranged between 0.50 (BW1) and 0.79 (BW2). Heritability estimates for LSB was 0.44 for BB rabbits, while no estimates were obtained for GG; the estimate for LWB was 0.37 and 0.10 for BB and GG, respectively. Repeatability estimates for all weights of doe and litter traits studied were higher for BB than for GG rabbits. The phenotypic correlations between doe weight and litter traits studied were positive and of moderate magnitude.

Introduction

The complex relationship between body weight and litter traits (size and weight) in litter-bearing species has been the subject of many discussions. Results of selection experiments have indicated that these traits are not under independent genetic control, but have led to conflicting conclusions about the nature of the relationship between them (Land, 1970). Recenty, Afifi and Kadry (1984) reported that doe weight during gestation is the result of her own weight plus the weight of her litter mediated by the size of this litter. Reviewed studies provided little evidence to link phenotypically the weights of doe during pregnancy with the size and weight of her litter at kindling.

The objectives of this study were: (1) to estimate the magnitude of some non-genetic effects affecting doe weight (at conception and during gestation) and litter size and weight at birth in Bauscat and Giza White rabbits, (2) to quantify the components of variance and covariance of these traits in a half-sib analysis, and (3) to estimate the heritability and repeatability of such traits. The phenotypic correlations between doe weight (at conception and during gestation) and litter size and weight at birth were also examined.

Materials and Methods

Data were collected on 218 litters of Bauscat (BB) and Giza White (GG) does produced during the period from September, 1977, to April, 1979, at the rabbitry of the Faculty of Agriculture at Moshtohor, Zagazig University, Egypt. Nulliparous does were mated at an average age of 10 months. At the beginning of the breeding season (September), the available females within each breed were randomly assigned to mating bucks with an average of 5 does to each buck. Full- and half-sib and sire-daughter matings were avoided. Further details of the breeding plan, management and feeding practices were reported by Afifi and Kadry (1984). Does were weighed at conception (BWC) and at 1st (BW1), 2nd (BW2), 3rd (BW3) and 4th (BW4) weeks of gestation. Litter size (LSB) and weight (LWB) at birth were recorded.

Data were available on 76 paternal half-sisters produced by 23 sires. Only sires with at least two daughters and each daughter with at least two litters were included in the analysis. The average number of litters per doe was 2.7. Litter traits in these analyses were considered to be traits of the doe; therefore, the reference to sires in this study means sire of the doe that produced the litter. Doe weight as well as litter traits were analysed for each breed separately by using mixed model analysis of variance techniques to estimate the fixed effects of year of birth of sire (5 years), year of production (2 years), month of conception (5 months) and parity (6 parities); see Table 2 and 3 for the classes represented for each fixed effect. Variance and covariance components were derived for random effects of sire of doe within birth year of sire, does within sire within birth year of sire and error (remainder). However, it was not possible to examine simultaneously all factors, and the interactions between them, which were likely to influence weight of doe rabbits, because the equations for estimation would have involved a matrix too large to invert. Harvey's (1977) mixed model computer program was utilized for analysing the data. Mean squares for sires within year of birth were used to test for significance of year-of-birth effects. Mean squares for does within sire within year of birth were used to test for significance of sires within year of birth. Tests of significance of all other effects were made by using the residual mean square.

Estimates of variance and covariance components were calculated by using Method 3 (Henderson, 1953). By equating mean squares of random effects to their expectations, estimates of variance components, i.e. sire (α^2s), doe within sire (α^2e) and remainder (α^2e) were obtained. Paternal half-sib heritability (h^2) estimates were calculated, across all parities, as four times the ratio of α^2s to the sum of α^2s, α^2d and α^2e. Repeatability (t) estimates were computed from the ratio $(\alpha^2s + \alpha^2d)/(\alpha^2s + \alpha^2d + \alpha^2e)$. Approximate standard errors for h^2 and t were computed from procedures described by Swiger et al. (1964). Phenotypic correlation coefficients (rp) between doe's weight (BWC, BW1,...,BW4) and litter traits (LSB and LWB) were calculated by using the formula outlined by Harvey (1977).

Results and Discussion

BB doe weight exceeded that of GG at conception and during gestation as expected (Table 1). Similarly, Affi and Kadry (1984) found that BB doe weight was higher than that of GG at conception and during pregnancy. LSB and LWB of GG rabbits were higher than those of BB (Table 1). Egyptian studies (Afifi et al., 1976a,b; Khalil, 1980; Afifi et al., 1982b; Afifi and Emara, 1984) have reported that LSB and LWB of GG rabbits exceed those of BB.

The increase in doe weight from BWC until BW4 was 444 and 453 grams in BB and GG, respectively (Table 1). Afifi and Kadry (1984) reported that doe weight during gestation is the result of her own weight plus the weight of her litter mediated by the size of this litter. Matheron and Mauleon (1979) stated that the biological functions of the doe and of her offspring simultaneously affect her litter traits during gestation. This means that a part of the expected variability is due to the individual genotype of the litter and a part to maternal and grandmaternal effects. Therefore, the observed differences between BB and GG doe weights studied might be due to breed differences in body weight (Afifi et al., 1980; Afifi and Kadry, 1984) and in size and/or weight of litter (Afifi et al., 1976a,b; Afifi et al., 1982b). Breed differences in prenatal growth rate of the litter and in rate of deposition of protein and fat in the mother during pregnancy may be another possible explanation (Eisen and Leatherwood, 1979).

For both breeds, LSB and LWB showed higher coefficients of variation than doe weight at conception and during gestation (Table 1). These higher coefficients of variation are more likely due to higher maternal effects on the litter during the prenatal period. However, the coefficients of variation of LWB include a contribution of the variation in nourishment of the fetuses (during the prenatal period of the pregnant doe).

Non-Genetic Effects

Birth Year of Sire. Effects of year of birth of sire on BB and GG doe weight studied were not significant (Tables 2 and 3). The same trend was also observed for LSB and LWB.

Year of Production. Body weight and litter traits of BB does kindled in 1978/79 were superior to those of animals kindled in 1977/78 (Table 2). A reverse trend was observed for GG does (Table 3). Year-of-production effects on doe weight and litter size and weight at birth were not significant for BB and GG rabbits (Tables 2 and 3). Afifi and Kadry (1984) reported that year-of-production effects were significant ($P < 0.05$) for doe weight at conception and highly significant ($P < 0.01$) for weight at weekly intervals during pregnancy in BB, GG, Baladi Red, Grey Giant Flander (Flemish Giant) and Baladi White rabbits. However, the effect of year of production, whether on body weight and/or litter size and weight at birth, is usually associated with differences in climatic conditions, severity of disease attack and age of doe (Afifi and Kadry, 1984).

Month of Conception. The heaviest BB doe weights, at different stages, were for does conceived during September and October (Table 2). The smallest sizes and lightest weights of litters were from does conceived during January. On the other hand, no consistent trend could be detected for month-of-conception effects on doe weight and litter size and weight of GG rabbits (Table 3).

Month of conception was one of the most important non-genetic factors ($P < 0.01$ or $P < 0.001$) influencing body weight of the doe during gestation (Tables 2 and 3). These observations could be explained on the basis of the amount and nutritive value of the available greens and of temperature during these months. Afifi and Kadry (1984) reported that season-of-conception effects were not significant for doe weight at conception and during gestation. Month-of-conception effects on LSB and LWB for both breeds under study (Tables 2 and 3) were not significant. Contrary to the present results, evidence was available in Egyptian studies on month-of-conception differences for LSB and/or LWB (Khalil, 1980; Khalil and Afifi, 1986; Khalil et al., 1987a).

Parity. BB doe weights at the 6th parity or more were heaviest at different stages of gestation, while the lightest weights were for animals at 1st parity (Table 2). This is because young does which have not reached adult size continue to grow during their first pregnancies and thus compete severely with their litters for available nutrients. Accordingly, the 6th parity in BB does recorded the largest LSB and heaviest LWB, while the 1st parity had the smallest LSB and lightest LWB (Table 2). Increase in LSB and/or LWB with advance of parity has been reported in different breeds of rabbits including the present ones (Granat and Zelnik, 1972; Afifi et al., 1976b; Khalil, 1980; Afifi et al., 1982b; Lukefahr et al., 1983, 1984). No clear trend for parity effect on doe weight and litter traits in GG rabbits could be detected (Table 3).

Parity, in general, had significant effects on doe weight studied in both breeds with the exception of BWC and BW4 in GG rabbits (Tables 2 and 3). Afifi and Kadry (1984) found that parity effects were significant ($P < 0.05$) for BW4; otherwise they were not significant for BWC or at other stages of gestation. Differences in LSB and LWB due to parity effects failed to prove significant for either breed (Tables 2 and 3). Parity effects on LSB and/or LWB were found to be nonsignificant by other investigators (Afifi et al., 1976a; Khalil, 1980; Afifi et al., 1982a,b: Lukefahr et al., 1983).

Random Effects

Sire-within-year effects were significant ($P < 0.05$) for BWC of BB rabbits and for all weights of GG, while they were not significant for BB doe weight during gestation (Table 4). Moreover, the proportions of the variance attributable to sire components for all GG doe weights studied were larger than those of BB rabbits. This might be because BB rabbits are more genetically uniform than GG rabbits, which have not previously been subjected to intensive selection during formation of the breed. Small or negative sire components of variance obtained for BB doe weight at all stages studied may be due to sampling effect and non-randomness in the distribution of daughters within sire groups of this breed. Maternal effects (among other things) on doe weight at all ages studied could be added as another cause in this respect. Mgheni et al. (1982) reported that, although maternal environmental effects decrease in relative importance after weaning, they are still present at sexual maturity, and this could complicate formation of conclusions, particularly in selection experiments for postweaning growth.

Results given in Table 4 indicate that differences in doe weight (at conception and during gestation) due to doe effects were highly significant ($P < 0.001$). Also, variation percentages due to doe effects in BB were larger than the corresponding percentages in GG. This is due to the superior maternal ability of BB does compared to that of GG does (Khalil, 1980).

The sire of doe affected ($P < 0.05$) LSB and LWB of BB rabbits, while nonsignificant effects for the corresponding traits in GG were observed (Table 4). Similar results were obtained by Khalil et al. (1987a). Consequently, improvement in LSB and LWB of BB rabbits could be made by selection of sires of does based on the performance of daughters for such traits. Doe-within-sire effects were not significant for litter traits studied in the two breeds (Table 4). This may suggest the existence of a negative covariance between adjacent litters. On the contrary, some investigators (Rouvier et al., 1973; Garcia et al., 1980; Blasco et al., 1982; Garcia et al., 1982; Lukefahr et al., 1983) reported that the doe contributes strongly to the phenotypic value of the size and weight of her litter not because of her direct gene transmission but mainly due to her maternal environmental effects on them. Differences in LSB due to doe effects may be attributed to differences in ovulation rate and preimplantation viability (Rouvier, 1979). Maternal effects determined by the number of mature, fertilized and established ova as well as the environment the doe provides for her litter and the genes she transmits to her litter during the prenatal period may be involved (Randi and Scossiroli, 1980).

Sire components of variance were smaller than those of doe components in BB and GG doe weight at all ages studied (Table 4). The same trend was observed for LSB and LWB of GG rabbits, while a reverse trend was observed for BB. The smaller proportions of variation in LSB and LWB in BB rabbits due to doe effects as compared to sire effects reflect a larger enviromental component of variance associated with the doe during gestation.

Heritability

Estimates of heritability (h^2) for BWC, BW1 and BW2 of BB rabbits ranged between 0.06 and 0.34, while estimates for BW3 and BW4 were not obtained because of the negative sire component of variance (Table 4). These estimates indicate that BB doe weights were subjected to a large environmental maternal influence. The estimates for GG doe weight at different stages ranged between 0.50 (for BW1) and 0.79 (for BW2). The estimates obtained in this study (the only available estimates) indicate that h^2 of GG doe weight during gestation tended to range between moderate and high in magnitude. Bogdan (1970) and Khalil et al. (1987b) concluded that h^2 estimates for body weight were the highest for weight at birth, declined to the lowest values at sexual maturity and increased (as did the estimates for GG rabbits, Table 4) again for body weight at 10 months or older. Khalil et al. (1987b) reported that h^2 estimates for body weight in rabbits differ widely in magnitude, and show marked effects of age.

Heritability estimates for LSB were 0.44 for BB and not obtained for GG, while the estimates for LWB were 0.37 and 0.10 for BB and GG, respectively (Table 4). High standard errors were associated with these estimates. Most of the reviewed h^2 estimates for LSB and LWB were low or moderate in magnitude (Randi and Scossiroli, 1980; Lahiri and Mahajan, 1982; Kadry and Afifi, 1984; Khalil et al., 1987a).

Repeatability

Repeatability (t) estimates for doe weight at different stages were generally higher for BB than for GG (Table 4). The present estimates of t for doe weight during gestation indicate that this trait is highly repeatable; estimates ranged from 0.64 to 0.83.

Estimates of t for LSB and LWB of BB were higher than those for GG (Table 4). Most results in the literature showed that LSB and LWB were of low or moderate t estimates (Rouvier et al., 1973; Suh et al., 1978; Lukefahr et al., 1983, 1984; Lahiri, 1984; Khalil, 1986; Khalil and Afifi, 1986). The low estimates of t obtained in the present and previous studies for LSB and LWB indicate the need for several records (several parities) before culling does for litter traits.

Phenotypic Correlation

Doe weight traits studied were positively correlated phenotypically with LSB and LWB in both breeds (Table 5). This is due to their part-whole relationship. The correlation coefficients were generally of moderate magnitude. Reviewed studies on litter traits in rabbits have indicated a favorable positive phenotypic correlation between weight of doe at kindling and size and weight of litter produced (Ragab and Wanis, 1960: Venge, 1963). The coefficients between BW4 and LSB and LWB were larger in magnitude than the coefficients between other doe weights studied and LSB and LWB. The coefficients between BW4 and LWB were larger than the coefficients between the same doe weight and LSB. It is rather difficult to know the exact nature of that correlation because of the associated environmental influences acting on the doe during gestation and at kindling.

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Table 1. Means ($\bar{X}$) ; standard deviations (SD) and coefficients of variation (CV) of uncorrected traits studied in BB and GG records.

Traits*	BB			GG		
	$\bar{X}$	SD	CV	$\bar{X}$	SD	CV
BWC	2994	362	12.1	2810	283	9.9
BW1	3111	513	16.6	2916	306	10.5
BW2	3200	352	10.9	3033	316	10.4
BW3	3308	341	10.3	3132	309	9.8
BW4	3438	353	10.2	3263	344	10.5
LSB	6.3	2.3	36.4	6.5	2.2	33.4
LWB	337	120	35.2	356	100	28.0

* Where BWC = weight of doe at conception (grams) ; BW1, BW2, BW3 and BW4 = weight of doe at 1st, 2nd, 3rd and 4th week of gestation (grams), respectively ; LSB and LWB = litter size (young) and weight (grams) at birth, respectively. The same notation was followed in other tables.

Table 2. Least-squares means ($\bar{X}$), standard errors (S.E.) and tests of significance of factors affecting weight of doe during gestation and reproductive traits at kindling in BB rabbits.

Independent Variable	BWC $\bar{X}$ ± S.E.	BW1 $\bar{X}$ ± S.E.	BW2 $\bar{X}$ ± S.E.	BW3 $\bar{X}$ ± S.E.	BW4 $\bar{X}$ ± S.E.	LSB $\bar{X}$ ± S.E.	LWB $\bar{X}$ ± S.E.
Birth year of sire	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1970/71	2983 ± 190	3072 ± 162	3166 ± 169	3330 ± 153	3431 ± 148	6.54 ± 0.93	348 ± 48
1972/73	2893 ± 180	2979 ± 154	3096 ± 160	3236 ± 145	3314 ± 140	6.01 ± 0.85	314 ± 45
1973/74	2861 ± 221	2936 ± 192	3045 ± 200	3183 ± 183	3284 ± 175	6.12 ± 1.03	278 ± 54
1974/75	2889 ± 198	3013 ± 184	3112 ± 190	3215 ± 178	3376 ± 171	5.80 ± 0.84	330 ± 45
1975/76	3029 ± 152	3158 ± 136	3292 ± 141	3388 ± 130	3574 ± 125	6.70 ± 0.68	375 ± 36
Year of production	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1977/78	2981 ± 41	3096 ± 59	3166 ± 40	3280 ± 39	3408 ± 40	6.19 ± 0.26	323 ± 14
1978/79	3027 ± 66	3151 ± 94	3288 ± 64	3382 ± 62	3516 ± 64	6.73 ± 0.42	371 ± 22
Month of conception	***	**	***	**	**	N.S.	N.S.
September-October	3140 ± 101	3160 ± 91	3281 ± 91	3360 ± 87	3473 ± 84	5.62 ± 0.66	308 ± 34
November	2926 ± 102	2940 ± 91	3092 ± 92	3226 ± 87	3436 ± 85	6.10 ± 0.67	327 ± 35
December	2987 ± 105	3148 ± 94	3213 ± 94	3328 ± 90	3418 ± 88	5.08 ± 0.72	297 ± 38
January	2770 ± 117	2966 ± 106	3110 ± 103	3279 ± 102	3410 ± 100	7.36 ± 0.93	382 ± 49
February-March	2831 ± 101	2943 ± 90	3014 ± 91	3129 ± 86	3240 ± 84	7.02 ± 0.64	331 ± 34
Parity	***	***	***	**	***	N.S.	N.S.
1 st	2579 ± 132	2694 ± 122	2747 ± 115	2894 ± 117	2957 ± 116	4.34 ± 1.17	217 ± 61
2 nd	2677 ± 115	2835 ± 104	2890 ± 102	3072 ± 100	3170 ± 98	6.63 ± 0.90	331 ± 47
3 rd	2802 ± 103	2967 ± 92	3082 ± 92	3226 ± 89	3294 ± 86	6.09 ± 0.69	301 ± 36
4 th	2948 ± 98	3098 ± 87	3201 ± 88	3326 ± 83	3432 ± 81	6.80 ± 0.59	354 ± 31
5 th	3142 ± 106	3187 ± 95	3384 ± 94	3472 ± 91	3685 ± 89	6.56 ± 0.74	375 ± 39
≥ 6 th	3437 ± 129	3408 ± 118	3548 ± 112	3597 ± 114	3836 ± 112	6.98 ± 1.12	397 ± 58

N.S. = nonsignificant , ** = $P < 0.01$ and *** = $P < 0.001$.